

[0022] FIGS. 18a-18e are schematic representations of a variety of geometries for the sensor as a capacitive sensor.

[0023] FIGS. 19a and 19b are schematic views of a first and second variation of the sensor as a pressure sensor, respectively.

[0024] FIG. 20 is a flow chart of the different operation modes of the preferred embodiments.

[0025] FIG. 21 is a schematic of the different input graphics, different cavity settings, and different user touches of the preferred embodiments.

[0026] FIG. 22 is a top view of the sensor that is a capacitive sensor with an X-conductor and a Y-conductor per cavity.

[0027] FIG. 23 is a top view of the sensor that is a capacitive sensor with fewer than an X-conductor and a Y-conductor per cavity.

[0028] FIGS. 24a and 24b are cross-sectional views of a support member between the layer and the substrate, with the cavity in a retracted volume setting and an expanded volume setting, respectively.

[0029] FIG. 24c is a top view of the support member.

[0030] FIG. 24d is a cross-sectional view of an alternative support member that partially defines the cavity.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0031] The following description of the preferred embodiments of the invention is not intended to limit the invention to these preferred embodiments, but rather to enable any person skilled in the art to make and use this invention.

[0032] As shown in FIGS. 1 and 2, the user interface system 100 of the preferred embodiments includes a sheet 110 that defines a surface 115 and a cavity 125, a volume of a fluid 120 contained within the cavity 125, a displacement device 130 that modifies the volume of the fluid 120 to expand the cavity 125 (thereby outwardly deforming a particular region 113 of the surface 115), and a sensor 140 that detects a force applied by a user that inwardly deforms the particular region 113 of the surface 115. As shown in FIG. 3, the user interface system 100 may also include a display 150 coupled to the sheet 110 and adapted to output images to the user and a processor 160 that is preferably coupled to the sensor 140 to receive signals from the sensor 140 and coupled to the displacement device 130 to send signals to the displacement device 130. The sensor 140 may also be located in between the sheet 110 and the display 150. However, any other suitable arrangement of the components of the system 100 may be used.

[0033] The user interface system 100 of the preferred embodiments has been specifically designed to be used as the user interface for an electronic device, more preferably in an electronic device that benefits from an adaptive user interface. The electronic device, which may or may not include a display, may be an automotive console, a desktop computer, a laptop computer, a tablet computer, a television, a radio, a desk phone, a mobile phone, a PDA, a personal navigation device, a personal media player, a camera, a watch, a remote, a mouse, a trackpad, or a keyboard. The user interface system 100 may, however, be used as the user interface for any suitable device that interfaces with a user in a tactile and/or visual manner. As shown in FIG. 2, the surface 115 of the user interface system 100 preferably remains flat until a tactile guidance is to be provided at the location of the particular region 113. The surface 115 of the user interface system 100 may also be deformed when a user input is required. At that time, the displacement device 130 expands the cavity 125 to

deform and/or expand the particular region 113 outward, preferably forming a button-like shape. With the button-like shape, the user will have tactile guidance when navigating for the expanded particular region 113 and will have tactile feedback when applying force onto the particular region 113 to provide input. The sensor 140 preferably senses the force that inwardly deforms the particular region 113. However, any other arrangement of the user interface system 100 suitable to providing tactile guidance and/or detecting user input may be used.

#### [0034] 1. The Sheet

[0035] As shown in FIGS. 1 and 2, the sheet 110 of the preferred embodiment functions to provide the surface 115 that interfaces with a user in a tactile manner and to at least partially define the cavity 125. The surface 115 is preferably continuous, such that when swiping a finger across the surface 115 a user would not feel any interruptions or seams. Alternatively, the surface 115 may include features that facilitate the user in distinguishing one region from another. The surface 115 is also preferably planar. The surface 115 is preferably arranged in a flat plane, but may alternatively be arranged in a curved or warped plane. The surface 115 also functions to deform upon an expansion of the cavity 125, and to preferably “relax” or “un-deform” back to a normal planar state upon retraction of the cavity 125. In one version, the sheet 110 contains a first portion that is elastic and a second portion that is relatively less elastic. In another version, sheet 110 is relatively more elastic in specific areas and relatively less elastic in other areas and is deformed by the expanded cavity 125 in the relatively more elastic areas. In another version, the sheet 110 is generally of the same elasticity. In yet another version, the sheet 110 includes or is made of a smart material, such as Nickel Titanium (commonly referred to as “Nitinol”), that has a selective and/or variable elasticity. The sheet 110 is preferably optically transparent, but may alternatively be translucent or opaque. In addition to the transparency, the sheet 110 preferably has the following properties: a high transmission, a low haze, a wide viewing angle, a minimal amount of back reflectance upon the display (if the display is included with the user interface system 100), scratch resistant, chemical resistant, stain resistant, relatively smooth (not tacky) to the touch, no out-gassing, and/or relatively low degradation rate when exposed to ultraviolet light. The sheet 110 is preferably made from a suitable elastic material, including polymers and silicon-based elastomers such as poly-dimethylsiloxane (PDMS) or RTV Silicon (e.g., RTV Silicon 615). In the version wherein the sheet 110 includes a first portion that is elastic and a second portion that is relatively inelastic, the inelastic portion is preferably made from a material including polymers or glass, for example, elastomers, silicon-based organic polymers such as poly-dimethylsiloxane (PDMS), thermoset plastics such as polymethyl methacrylate (PMMA), photocurable solvent resistant elastomers such as perfluoropolyethers, polyethylene terephthalate (PET), or any other suitable material. The sheet 110 may, however, be made of any suitable material that provides the surface 115 that deforms and defines a cavity 125. The sheet 110 may be manufactured using well-known techniques for micro-fluid arrays to create one or more cavities and/or micro channels. The sheet 110 may be constructed using multiple layers from the same material or from different suitable materials, for example, the sheet 110 may include a layer portion 116 of one material that defines the surface 115 and a substrate portion 118 of a second material (as shown in FIG. 4).